

NeSS02 - Solar Neutrinos

Solar Neutrino Detection in KamLAND



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KamLAND - Kamioka Liquid Scintillator (Anti)neutrino Detector

I. Reactor $\bar{\nu}_e$:

study $\bar{\nu}_e$ oscillation in solar km^2 region

coincidence: $\bar{\nu}_e + p \rightarrow e^+ + n$

Prompt: e^+ annihilation

Delayed: n capture (180 μs)

rate: $\sim 2/\text{day}$

II. ^{7}Be Solar $\bar{\nu}_e$:

study ^{7}Be solar $\bar{\nu}_e$ oscillation

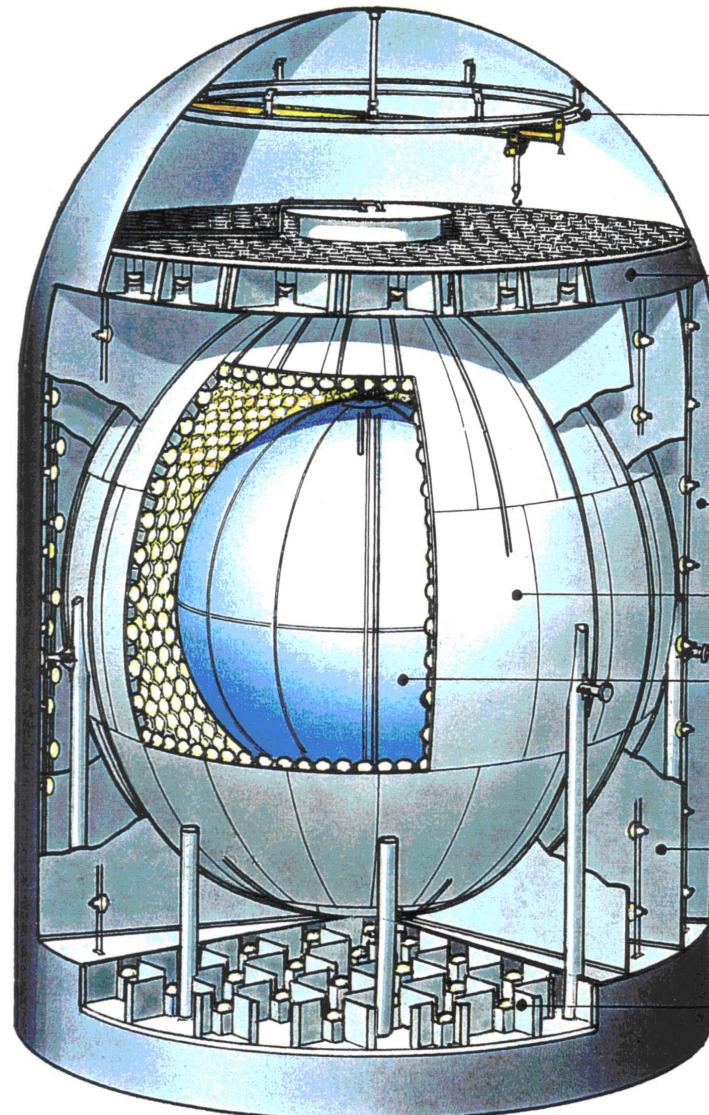
signal: $\bar{\nu}_e + e^- \rightarrow \bar{\nu}_e + e^-$

rate: $\sim 300/\text{day}$

$\sim 120/\text{day}$ for $R \leq 5\text{m}$

1st Phase: Reactor neutrinos, $E > \sim 1 \text{ MeV}$

2nd Phase: Solar neutrinos, $E < 1 \text{ MeV}$



KamLAND - Kamioka Liquid Scintillator (Anti)neutrino Detector

1 kton liquid scintillator

80% dodecane

20% pseudocumene

1.5 g/L PPO

Nylon Balloon

Paraffin outside the balloon

radon barrier

1879 PMT's

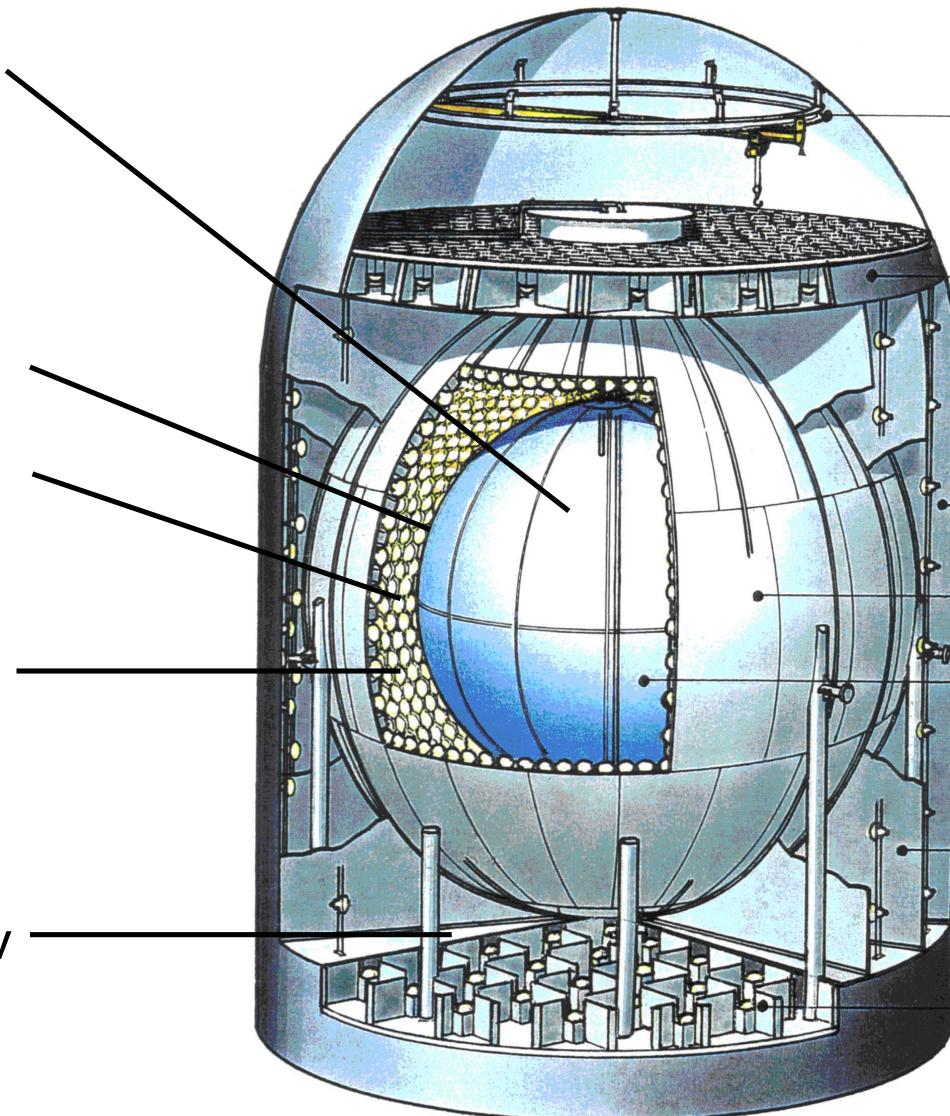
1325 17" (fast)

544 20" (efficient)

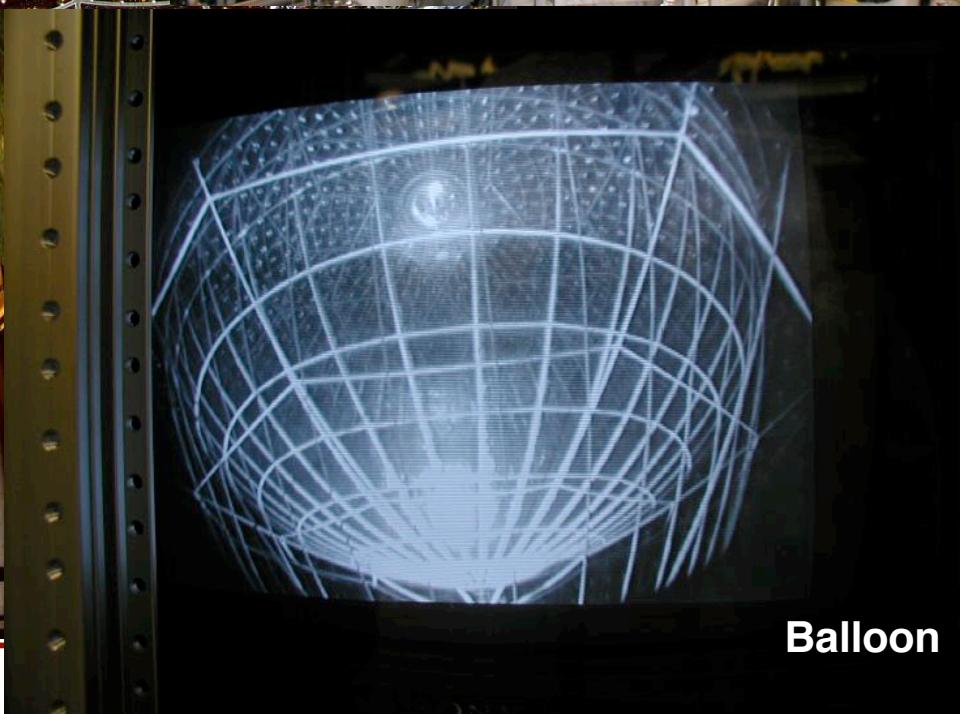
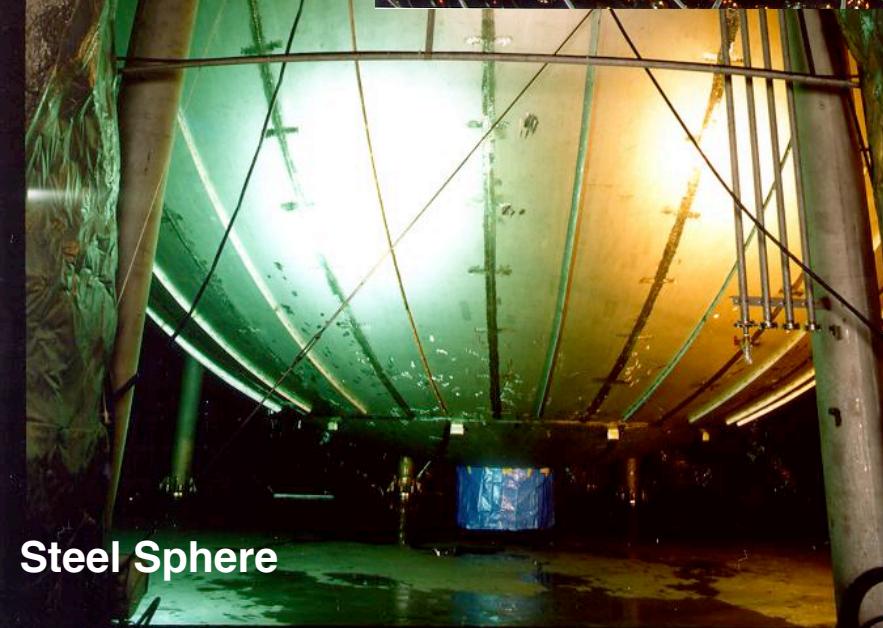
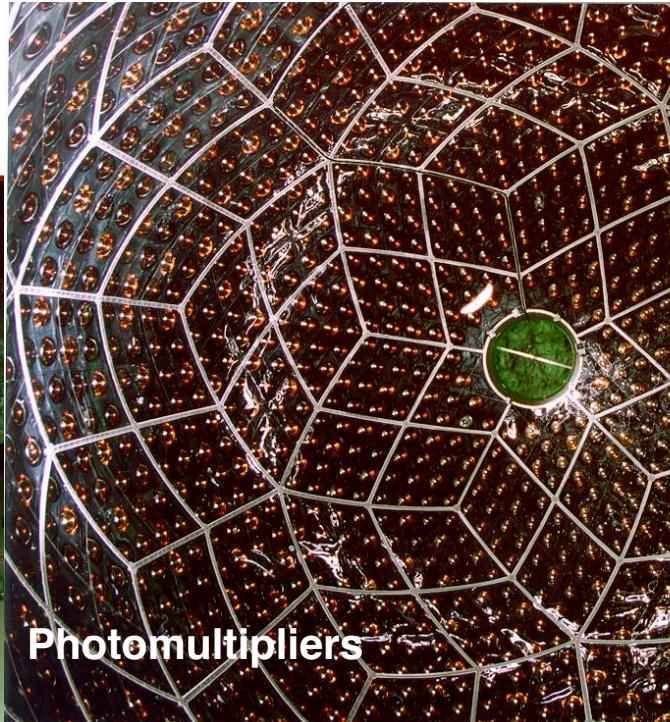
34% coverage

Outer Detector: Water Cherenkov

225 20" veto PMT's



KamLAND



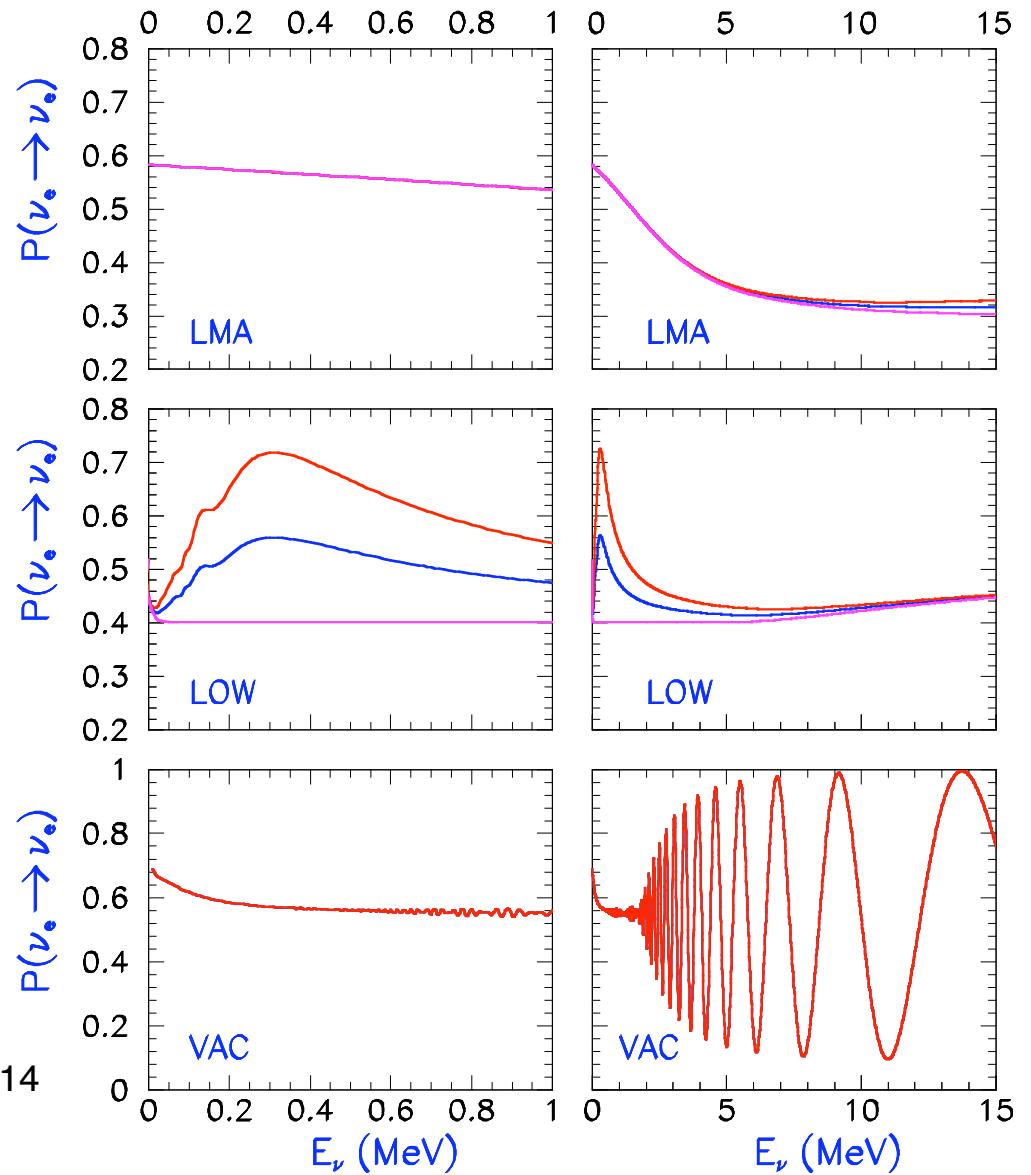
KamLAND Physics with Solar Neutrinos

Test Neutrino Oscillation Solutions

- currently favored solutions have same behavior at high energies
- different behavior at low energies

Survival probabilities for best fit allowed solutions

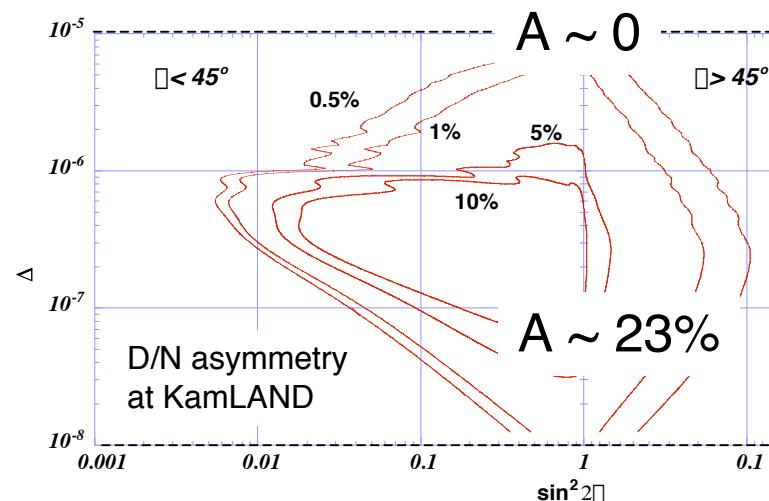
Bahcall et al. hep-ph/0204314



Day-Night Effect of ${}^7\text{Be}$ Solar Δ_e at KamLAND

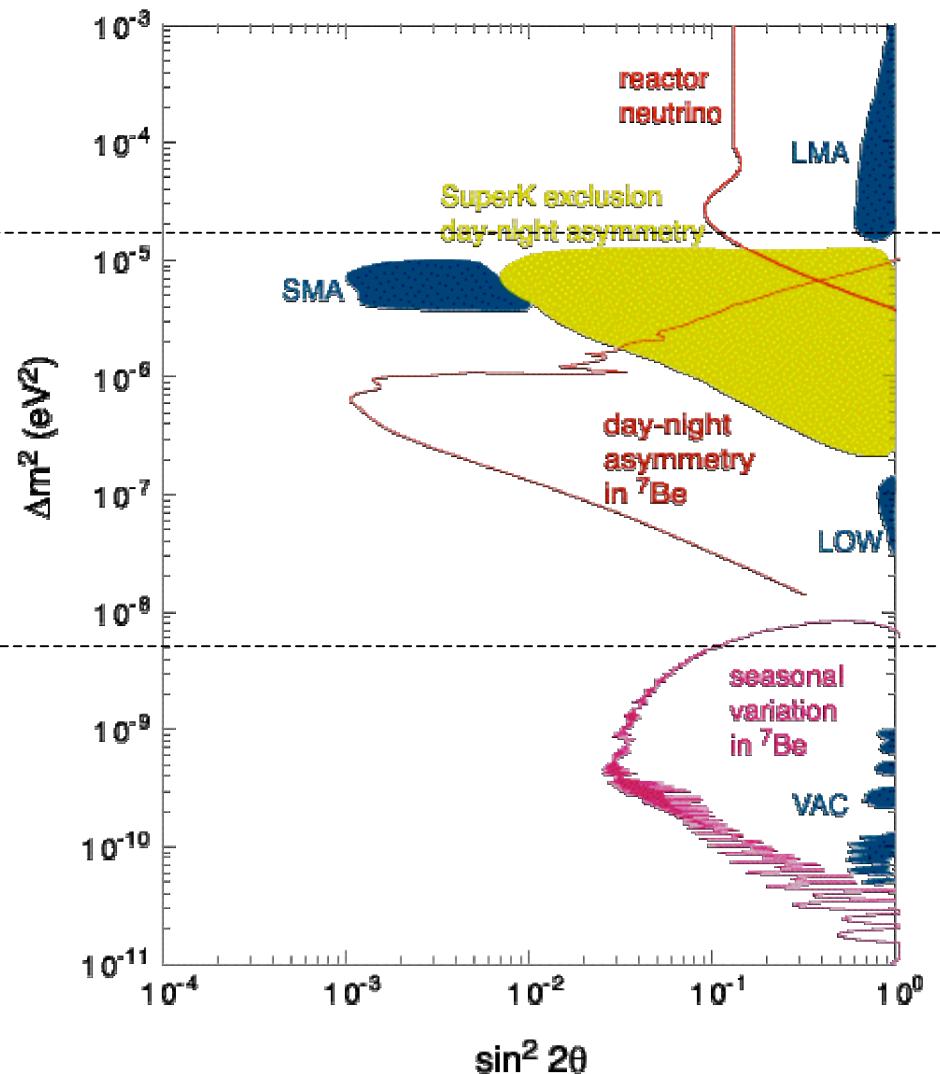
Day-Night Asymmetry Contours

Monoenergetic ${}^7\text{Be}$ Δ_e well suited for the measurement of D/N and annual variations.



Gouvea et al. hep-ph/9910286

- ☐ may help distinguish LOW vs LMA
- ☐ can provide evidence for matter effect

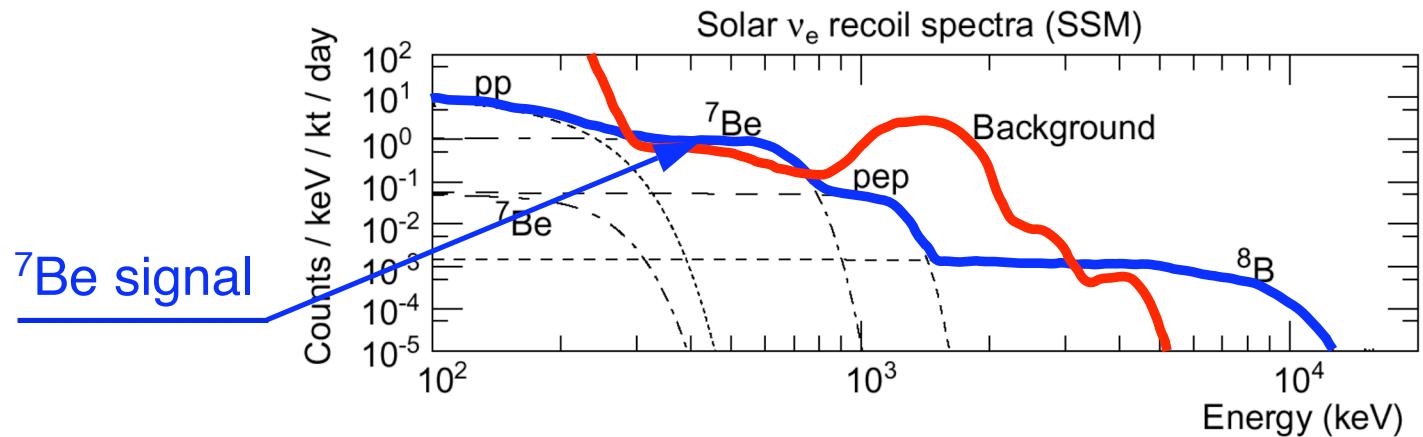
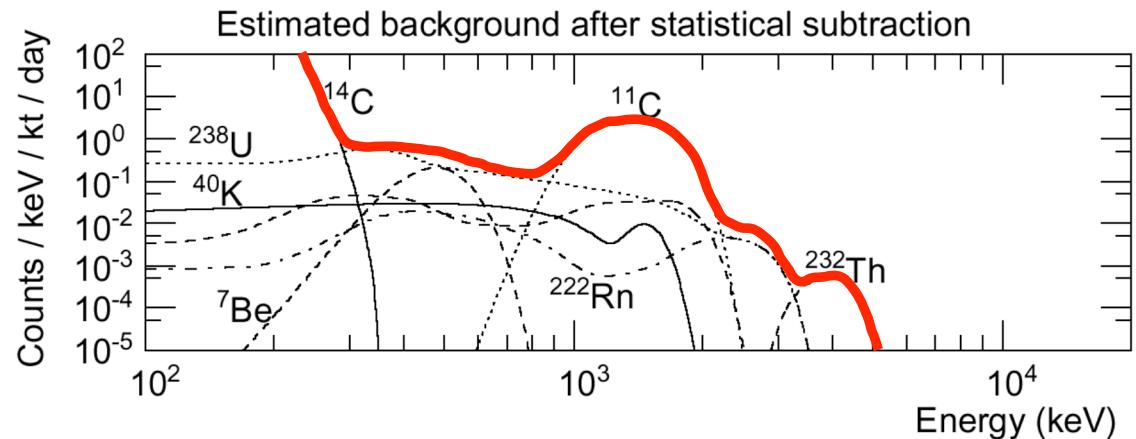


Solar Neutrinos at KamLAND

Direct Detection of ${}^7\text{Be}$ Neutrinos

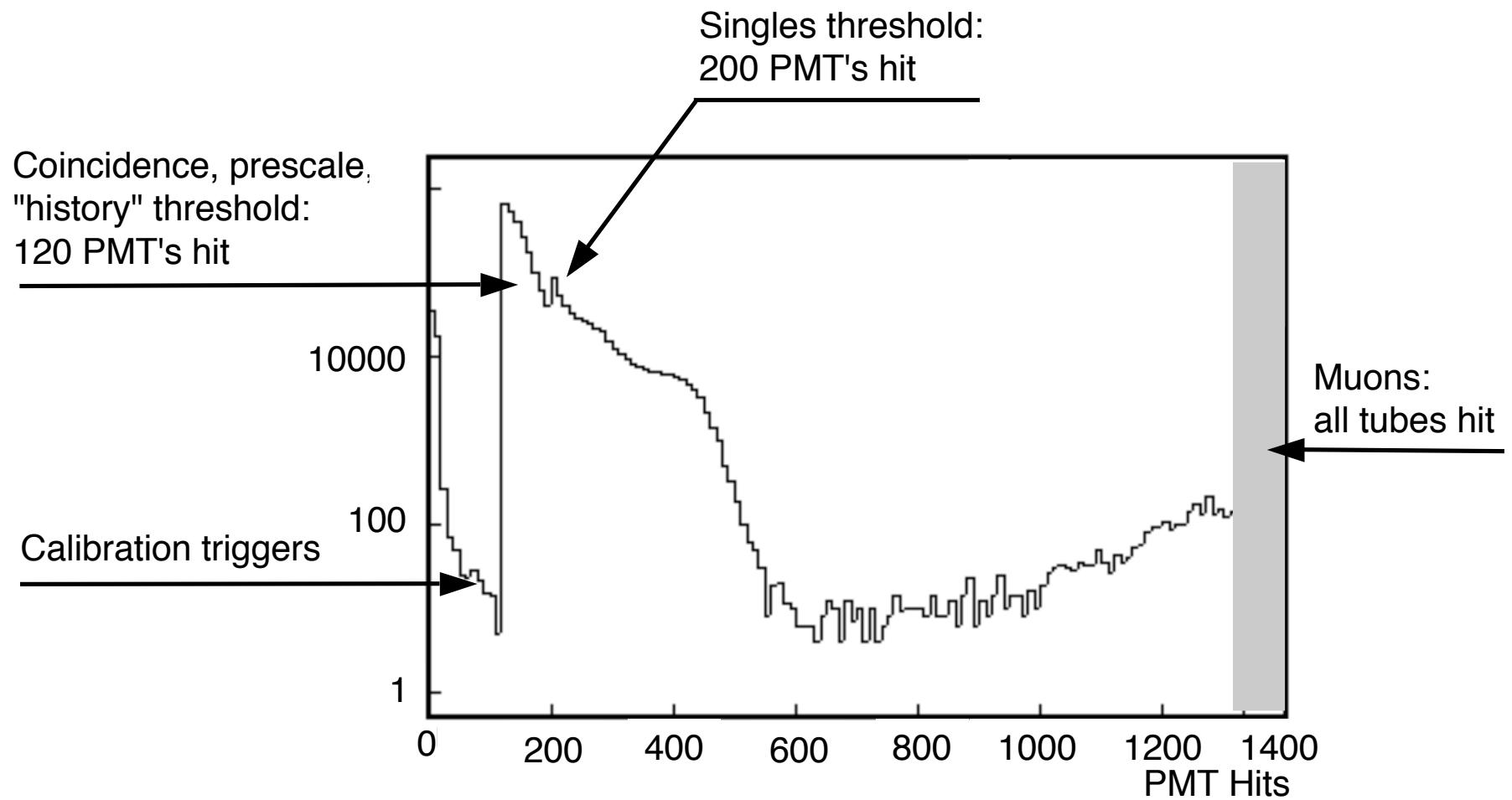
- Singles measurement,
i.e. no coincidence signal
- Low backgrounds required

KamLAND proposal*



*not our current estimate of low-energy backgrounds!

KamLAND Data: Raw Spectrum

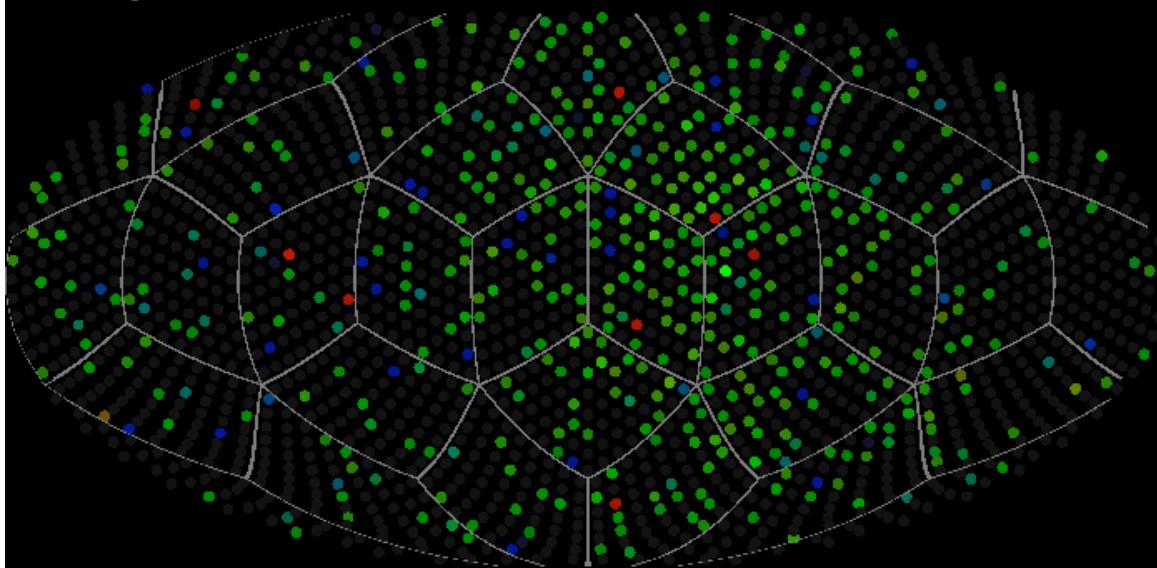


KamLAND data taking started January 22, 2002

KamLAND Data: Event

```
KamLAND Event Display  
Run/Subrun/Event : 207/0/1358102  
UT: Tue Jan  1 02:28:01 2002  
TimeStamp : 279045286418  
TriggerType : 0xb00 / 0x2  
Time Difference 208 micro sec  
NumHit/Nsum/Nsum2/NumHitA : 500/245/474/0  
Total Charge : 893 (0)  
Max Charge (ch): 10.8 (650)
```

(no OD hits)



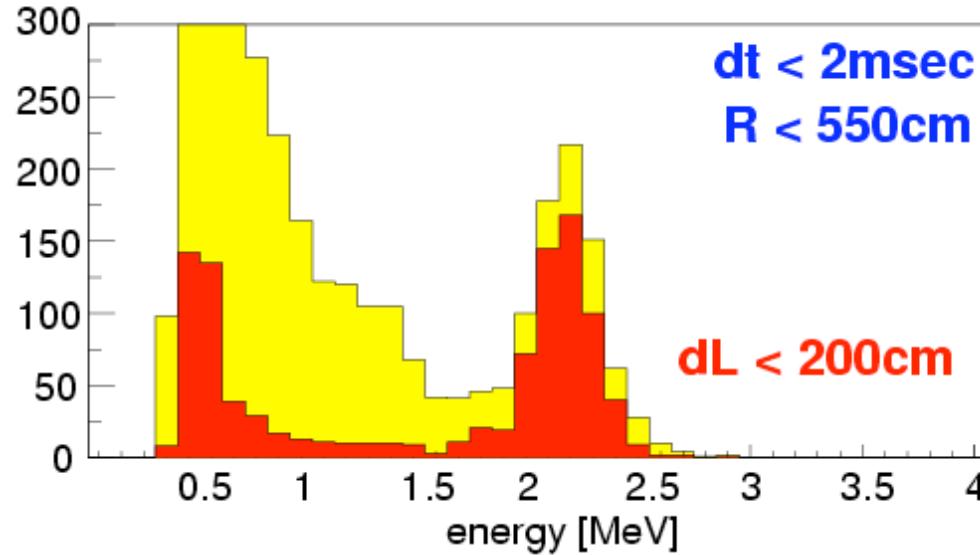
T : 575 585 595 605 615 625 635 645 655 665 675 685 695 705 715 725

Low-Energy Event

neutrino?
background?

color is time

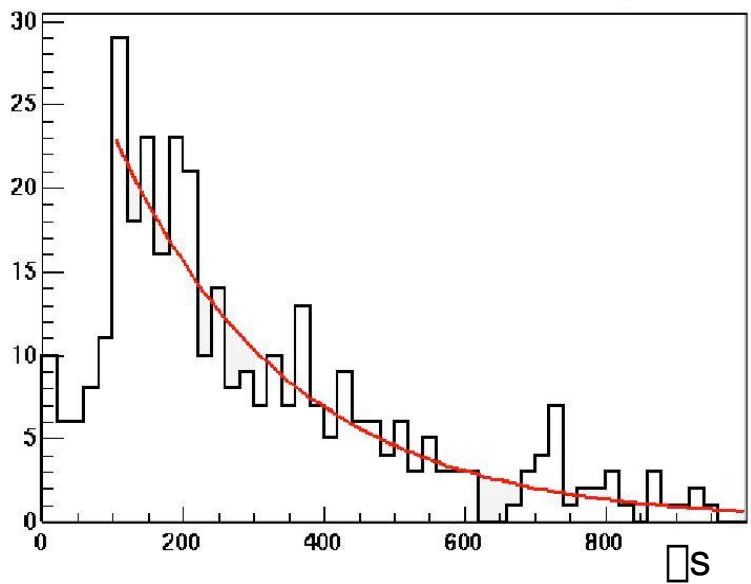
KamLAND Data: Spallation Neutrons



Capture time of $189 \pm 19\text{ }\mu\text{s}$
consistent with the expected
value of $180\text{ }\mu\text{s}$

Energy consistent with a
2.2 MeV neutron capture

Time since muon



KamLAND Data

Radial Distribution of Events

With $1/R^2$ weight

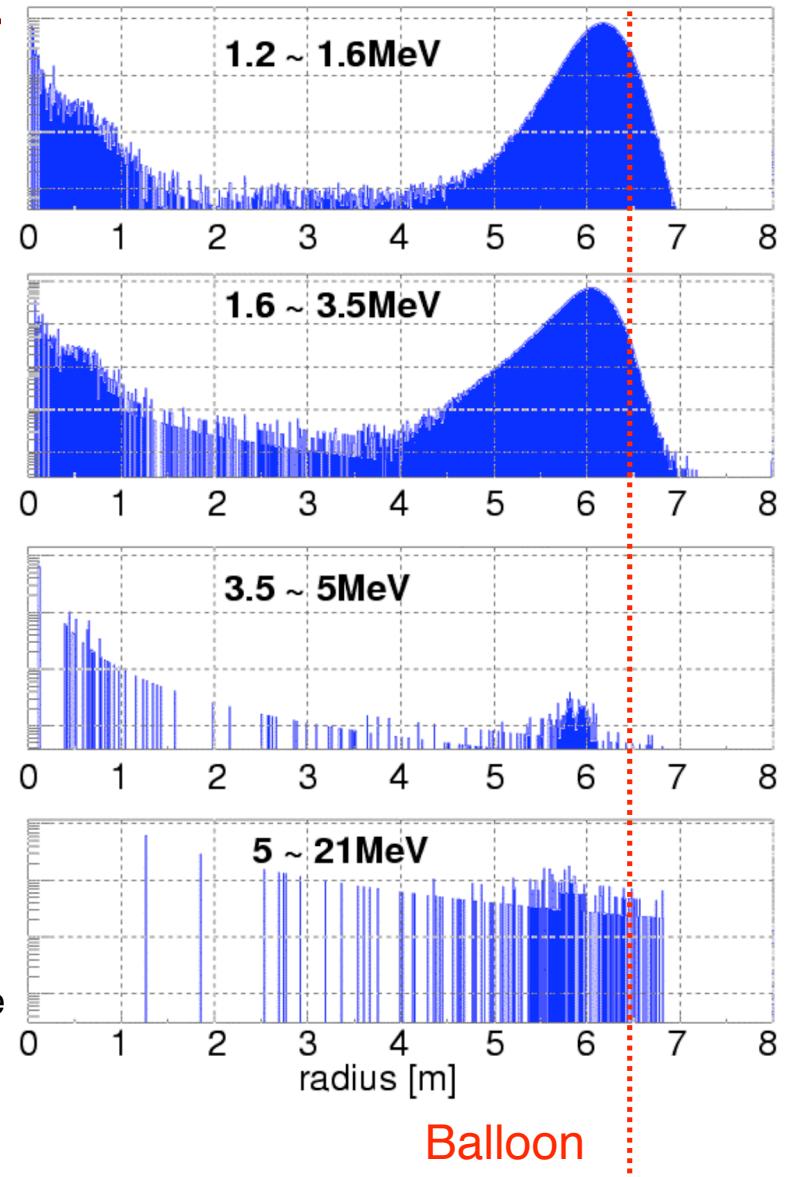
Rope (^{40}K)
Rock \square (U, Th, K)
PMT \square (U, Th, K)

PMT, Rock
 ^{208}TI \square

Rock \square
neutrons

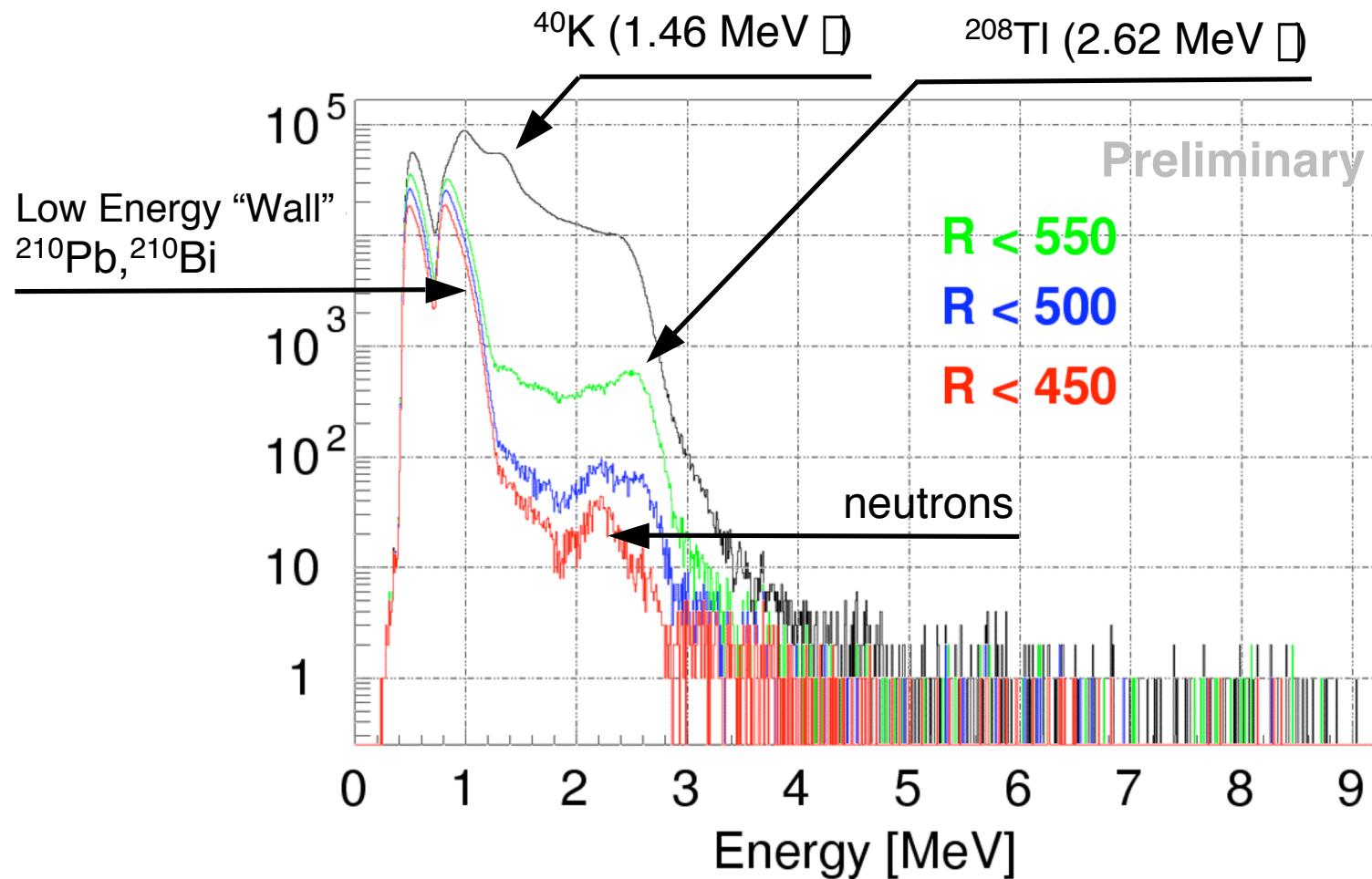
Most backgrounds peak
near the **balloon**, the edge of the
scintillator volume

log scale



KamLAND Data

Energy Spectrum and Fiducial Volume

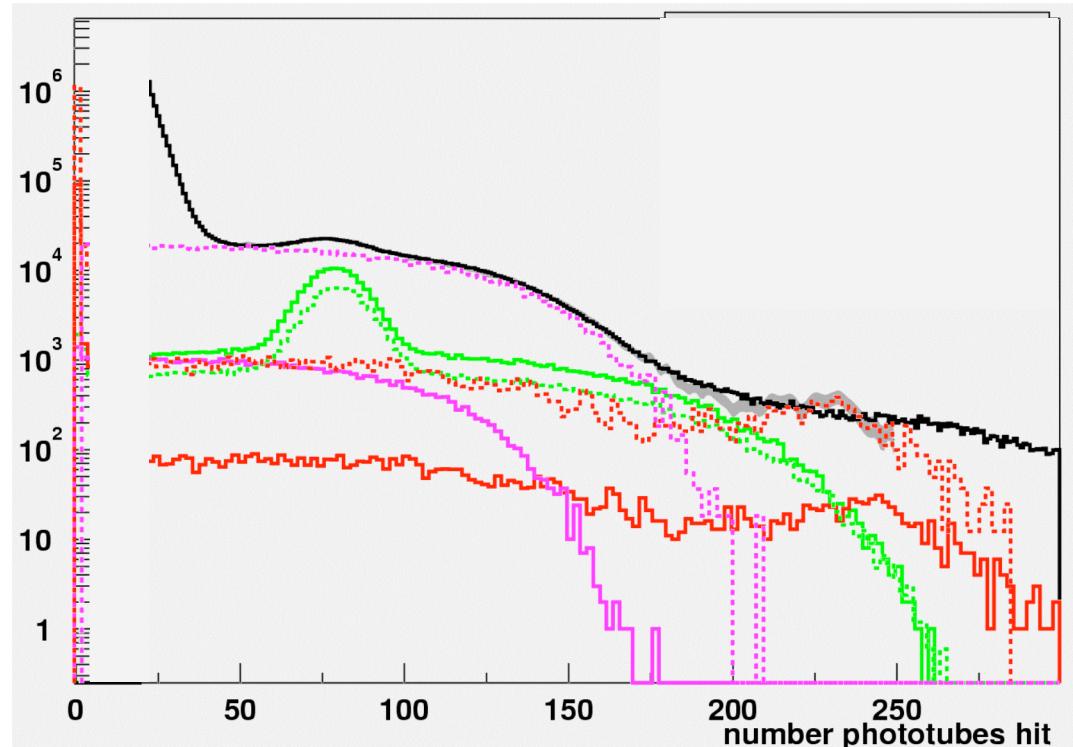


Backgrounds for Solar Neutrino Detection: Data

Low-Energy Spectrum

Rates

Data	~750 Hz
^{210}Pb	~100 Hz
^{85}Kr	~600 Hz
other bkgds.	~50 Hz



- Dominant low-energy backgrounds: ^{85}Kr
 $^{210}\text{Pb}, ^{210}\text{Bi}$ (from Rn decays)
- Working on purification and eliminating leaks

Backgrounds for Solar Neutrino Detection

Radiopurity Design Goals and Measurements

	<i>Requirements (LS)</i>	<i>Requirements (BO)</i>	<i>Measurement</i>
^{238}U (^{226}Ra)	$< 10^{-16} \text{ g/g}$	$< 10^{-14} \text{ g/g}$	$< 6.4 \times 10^{-16} \text{ g/g}$
^{232}Th (^{228}Ra)	$< 10^{-16} \text{ g/g}$	$< 10^{-14} \text{ g/g}$	$< 2 \times 10^{-16} \text{ g/g}$
^{40}K	$< 10^{-14} \text{ g/g}$	$< 10^{-12} \text{ g/g}$	$< 2.3 \times 10^{-16} \text{ g/g}$
Rn	$< 10 \text{ kBq/m}^3$	$< 100 \text{ kBq/m}^3$	$< 5-10 \text{ mBq/m}^3$

Sources of Backgrounds

Air

^{85}Kr

1-2 Bq/m³

Rn

< 5-10 mBq/m³

- Backgrounds **acceptable for reactor experiment:**
Accidental coincidence rate ~ 0.004 events/day ($R \leq 5\text{m}$)
- Need **background reduction for solar experiment:**
Rn-free N_2/Air supply
Reduce Rn emanation (inner pipe surfaces, leaks etc.)

Summary

1st Phase: KamLAND reactor antineutrino experiment

- KamLAND continues to make rapid progress
- Background levels are acceptable for the reactor experiment

2nd Phase: KamLAND solar neutrino and geo-neutrino experiment

- Will require lower backgrounds, possibly purification and re-circulation for both LS and BO, with particular attention to Kr removal
- R&D on purification systems:
 - Kr/Ar/Rn free N₂/air supply
 - ²¹⁰Pb removal from LS
 - Noble gas removal from LS (N₂ stripping) and water (degassing)
 - Leak protection in mechanical systems

- Interesting physics in ⁷Be solar neutrinos.
- Proposal for ^{2nd} KamLAND phase (⁷Be solar □) likely
(if Kr and Pb backgrounds can be reduced).



KamLAND Collaboration

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